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# CHEMICAL DEFENSE FLIGHT GLOVE ENSEMBLE EVALUATION (U)



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*ANTHROPOLOGY RESEARCH PROJECT, INC.*

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FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
Armstrong Aerospace Medical Research Laboratory

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Four chemical defense flight glove ensembles were evaluated for their effect on manual dexterity. Two- and three-layer combinations included in the study were: cotton liner/7 mil butyl/Nomex; cotton liner/12.5 mil epichlorohydron butyl/Nomex; Nomex/7 mil butyl (no liner); and, Nomex/12.5 mil epichlorohydron butyl (no liner). Fifteen male and 15 female subjects performed five dexterity tests bare-handed and while wearing each of the glove ensembles. Results indicated that, as expected, all gloved conditions produced significantly poorer performances than did the bare-handed condition, and two-layer combinations resulted in consistently better performances than did the three-layer combinations. Although subjects' performances were least impaired by the Nomex/butyl 7 combination, the butyl 7 gloves tended to tear. For this reason, the two-layer combination of Nomex/epichlorohydron butyl 12.5 appears to be the most practical ensemble. Keywords:

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## SUMMARY

The Air Force is considering replacing its current chemical defense flight glove ensemble with one which affords similar protection but does not so greatly impede manual performance.

The object of this study was to determine which of four candidate CD flight glove combinations would cause the least loss of manual dexterity.

The following glove combinations were evaluated:

- Cotton liner/7 mil butyl CD glove/Nomex flight glove
- Cotton liner/12.5 mil epichlorohydron butyl CD glove/Nomex flight glove
- Nomex glove/7 mil butyl (no liner)
- Nomex glove/12.5 mil epichlorohydron butyl (no liner)

Fifteen male and fifteen female subjects performed 5 dexterity tests (Minnesota Rate of Manipulation Turning Test, O'Connor Finger Dexterity Test, Pennsylvania Bi-Manual Worksample - Assembly, Roeder Manipulative Aptitude Test - Rods and Caps, and the Purdue Pegboard Assembly Test) bare-handed and while wearing the four glove ensembles.

As expected, the results showed that all gloved conditions were significantly worse than the bare-handed condition, and that subjects wearing the two-layer combinations performed better than they did in the three-layer ensembles. The best test scores were obtained by subjects wearing the 7 mil butyl glove over the Nomex flight glove. Since the butyl glove was prone to tearing, however, it appeared that the two-layer 12.5 epichlorohydron butyl-over-Nomex ensemble is the most practical.

## PREFACE

This study was conducted by the Anthropology Research Project, Inc. under Air Force Contract F33615-85-C-0531 (Task 718408) with the U.S. Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

The authors would like to thank Captain Jerry Brown, Human Systems Division, Brooks Air Force Base, for his support of the project and for providing the gloves worn by the subjects during testing. They would like to thank Ms. Kathleen Robinette of the Workload and Ergonomics Branch, Human Engineering Division, Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, for her support as contract monitor. They also wish to acknowledge Ms. Donna Bagdonovich for supplying the glove liners.

Ms. Ilse Tebbetts, Ms. Belva Hodge and Ms. Sherri Upchurch edited and prepared the manuscript for publication.

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### INTRODUCTION

The Air Force currently issues to its aircrews a chemical defense (CD) glove ensemble consisting of cotton gauntlet-style liners, 7 mil* butyl chemical defense gloves, and fire resistant Nomex flight gloves with leather palms (Figure 1). Consideration is being given to changing this ensemble to one which affords similar protection but does not so greatly impede manual performance.

Figure 1. The cotton liner, butyl chemical defense glove, and Nomex flight glove.

The object of this study was to determine which of several candidate CD flight glove combinations would cause the least loss in dexterity. The durability and comfort of the gloves were also examined.

Investigators administered a battery of dexterity tests to 30 subjects, alternately bare-handed, and wearing each of several two- and three-layer ensembles including the currently issued ensemble. Test scores were compared and, as expected, results indicated that subjects tended to perform best without gloves and better with either of the two-glove combinations than with the three-layer ensembles. Furthermore, the two-glove ensembles felt more comfortable to the subjects than the three-glove combinations.

Procedures and results of the tests are fully described in the following sections.

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* One mil = 1/1000 inch (thickness).

EXPERIMENTAL DESIGN

Four candidate CD flight glove ensembles were examined to identify which combination would maximize performance. Also included in the study as a base line was an evaluation of bare-handed performance. The glove ensembles tested are listed in Table 1. They include two two-layer combinations in which the Nomex glove is worn underneath (Figure 2), thereby eliminating the need for the liner normally required to absorb perspiration when butyl gloves are worn. The first glove combination listed (Ensemble I) is the current Air Force issue (Figure 3).

TABLE 1

GLOVE ENSEMBLES

| Ensemble | First Layer | Second Layer | Third Layer |
|---|---|---|---|
| I | cotton liner | 7 mil butyl (B 7) | Nomex |
| II | cotton liner | 12.5 mil eco-butyl (EB 12.5) | Nomex |
| III | Nomex | 7 mil butyl | ---- |
| IV | Nomex | 12.5 mil eco-butyl | ---- |

Figure 2. Chemical defense glove worn over Nomex flight glove.

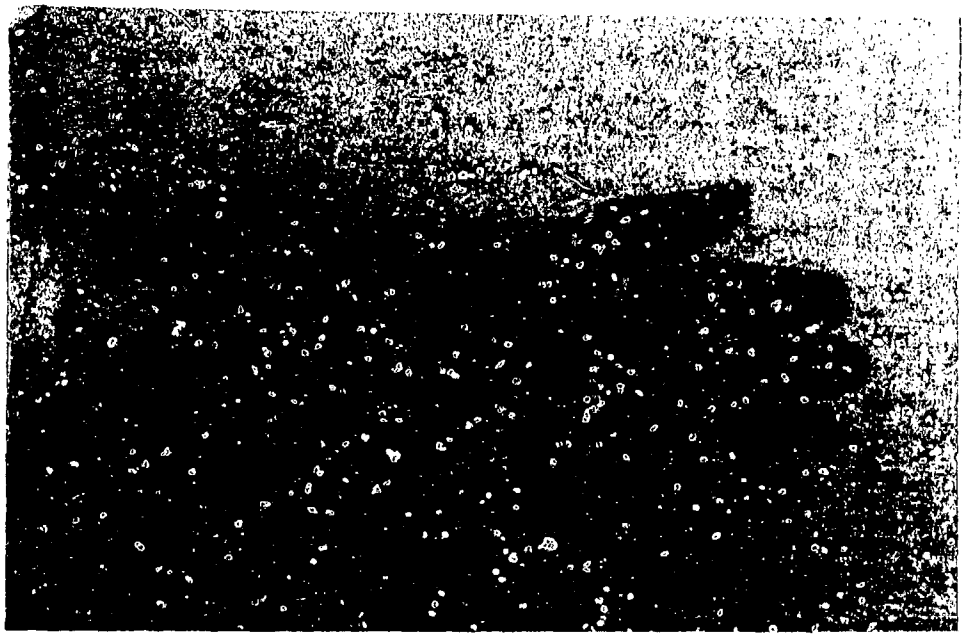


Figure 3. Liner, butyl 7, Nomex overglove.

Subjects

The 30 subjects who participated in the study were paid volunteers from an established subject pool at Systems Research Laboratories, Beavercreek, Ohio. The ages of the 15 female subjects ranged from 19 to 40 years (mean age: 25); ages of the 15 males ranged from 19 to 36 years (mean age: 24). Subjects were selected without regard to age, handedness, or previous experience.

To document the representativeness of subjects with regard to hand size, and to identify any unusual size or proportion that might cause misleading results, 15 anthropometric measurements of each subject's dominant hand were taken by the same experimenter. The measurements, described and illustrated in Appendix A, include the following: hand breadth, digit lengths, crotch heights, thumb circumference, and four finger circumferences (at the base and at the tip of the middle and index fingers). Summary statistics for 11 of the measurements taken in this study are compared to similar measurements obtained in previous Air Force anthropometric studies in Tables 2 and 3. The females from the present study are compared to Garrett's (1970a) female hand study and the Air Force anthropometric survey conducted in 1968 (Clauser et al., 1972). The males are compared to Garrett's (1970b) male hand study and the Air Force anthropometric survey of male flying personnel conducted in 1967 (Churchill, Kitka and Churchill, 1977). Listed are the sample sizes (n), means, and standard deviations (SD).

TABLE 2

COMPARISON OF HAND ANTHROPOMETRY (FEMALES)
(values in centimeters)

| Variable | Present Study Females n=15 Mean | SD | USAF Females 1968 n=1905 Mean | SD | Garrett Females 1970 n=211 Mean | SD |
|---|---|---|---|---|---|---|
| Hand Length | 17.23 | 0.84 | †18.38 | 0.96 | 17.93 | 0.86 |
| Hand Breadth | 7.83 | 0.26 | 7.55 | 0.39 | 7.71 | 0.38 |
| Crotch 1 Ht | 5.97 | 0.36 | Not measured | | *5.72 | 0.56 |
| Crotch 2 Ht | 9.51 | 0.51 | " | " | *9.86 | 0.60 |
| Crotch 3 Ht | 9.39 | 0.56 | " | " | *9.81 | 0.59 |
| Crotch 4 Ht | 8.39 | 0.49 | " | " | *8.72 | 0.60 |
| Digit 1 Length | 10.16 | 0.97 | " | " | *11.50 | 1.00 |
| Digit 2 Length | 16.43 | 0.71 | " | " | *16.67 | 0.89 |
| Digit 3 Length | 17.23 | 0.85 | " | " | *17.65 | 0.87 |
| Digit 4 Length | 16.23 | 0.83 | " | " | *16.76 | 0.89 |
| Digit 5 Length | 13.76 | 0.74 | " | " | *14.64 | 0.92 |

† Measured from the level of the radial styloid; in the other studies, from the wrist crease.

* Garrett measured with digits separated. Digits were touching for the present study.

TABLE 3

COMPARISON OF HAND ANTHROPOMETRY (MALES)
(values in centimeters)

| Variable | Present Study Males n=15 Mean | SD | 1967 Survey of Flying Personnel n=2420 Mean | SD | Garrett Males 1970 n=148 Mean | SD |
|---|---|---|---|---|---|---|
| Hand Length | 18.37 | 0.85 | 19.11 | 0.82 | 19.72 | 0.93 |
| Hand Breadth | 8.78 | 0.47 | 8.90 | 0.42 | 8.96 | 0.40 |
| Crotch 1 Ht | 6.35 | 0.43 | Not measured | | 6.81 | 0.60 |
| Crotch 2 Ht | 10.19 | 0.68 | " | " | *11.05 | 0.60 |
| Crotch 3 Ht | 10.07 | 0.62 | " | " | *10.87 | 0.58 |
| Crotch 4 Ht | 9.02 | 0.55 | " | " | *9.72 | 0.51 |
| Digit 1 Length | 10.05 | 1.00 | " | " | †10.03 | 0.92 |
| Digit 2 Length | 17.39 | 0.81 | " | " | *18.32 | 0.88 |
| Digit 3 Length | 18.37 | 0.85 | " | " | *19.52 | 0.92 |
| Digit 4 Length | 17.41 | 0.78 | " | " | *18.20 | 0.88 |
| Digit 5 Length | 15.01 | 0.83 | " | " | †14.60 | 0.80 |

* Garrett measured with digits separated. Digits were together for the present study. Measurements termed Digit Lengths in the present study were termed Digit Heights in Garrett's study.

† Since Garrett measured with fingers separated, Digit 1 Length and Digit 5 Length in the present study are not comparable to his Digit 1 and 5 Heights.

Hand dimensions of the test sample population appear to be slightly different, on the average, from those of the Air Force population (male subjects' hands tended to be shorter, females' hands broader and shorter). However, the dexterity test results for the sample are considered applicable to the AF population because test subjects' measurements fall within the range of those found among Air Force personnel and, in any case, there was no significant correlation between these measurements and bare-handed test scores.

## Glove Size Selection

All sizes of all types of gloves were available for the test. Subjects were first asked to select the liner they felt fit them best. The liners, which come in sizes small, medium and large, tend to stretch a great deal, and no subject chose the large size.

CD glove size was determined using EB 12.5 gloves because B7 gloves tend to stretch more. With the liners on, subjects were asked to select a pair of EB 12.5 gloves from the five sizes available and subsequently wore the same size in B7 gloves. Subjects then selected the Nomex size they preferred. Most subjects needed two Nomex sizes: one to wear outside the CD gloves and a smaller size to wear inside.

Figures 4 through 9 show the location of the test subjects on bivariate frequency distribution tables of male and female USAF surveys. Each subject's choice of glove size is superimposed on them.

The distribution of glove sizes chosen, with respect to hand breadth and hand length, indicates that subjects' evaluations of fit vary a great deal according to individual preference for tighter or looser fit. The sizes chosen in Nomex and CD gloves do not appear to be correlated with hand length or breadth.

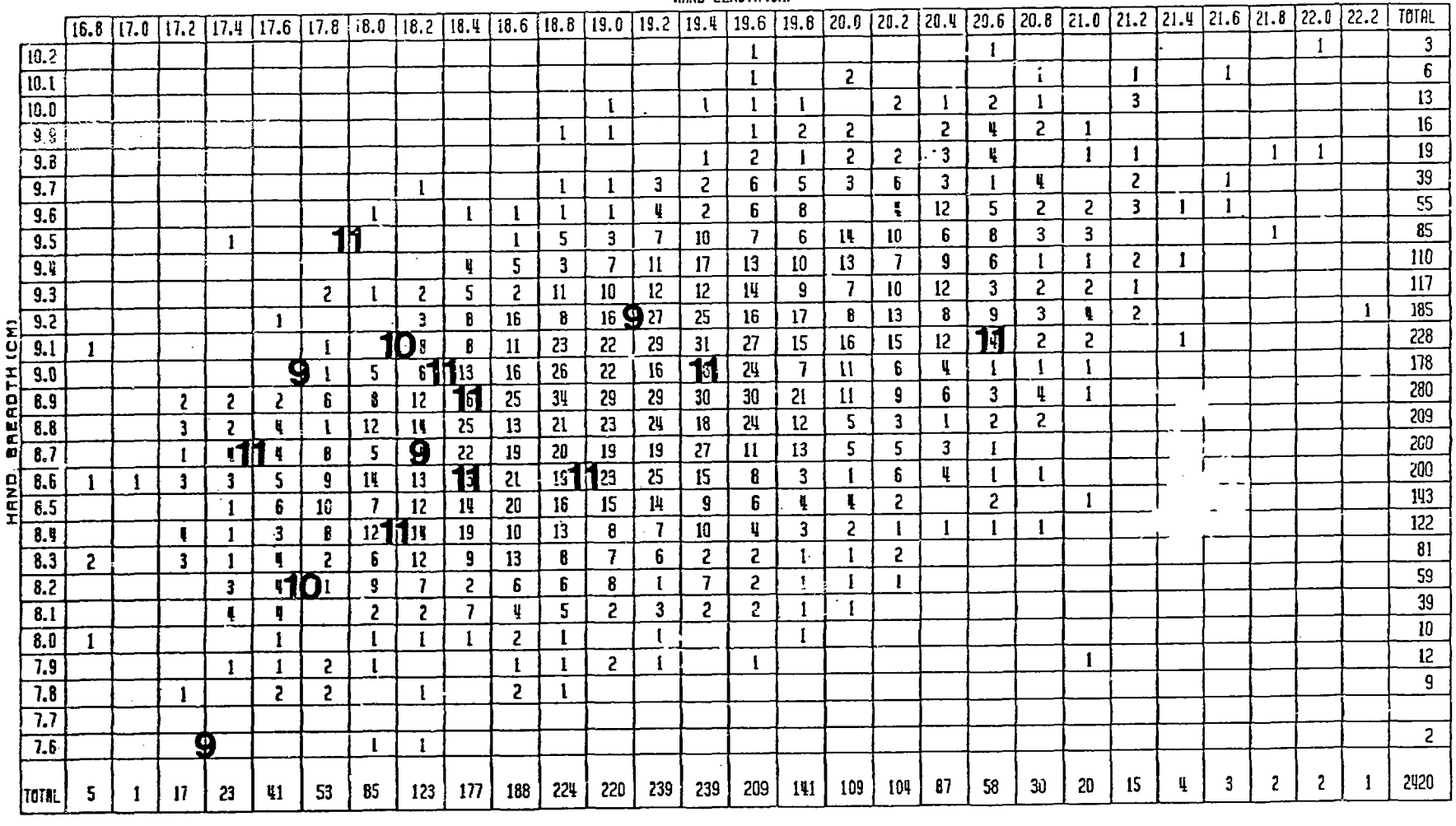
Of the 30 subjects who completed the tests, one female wore the smallest available size Nomex (#8) both over and under the CD gloves, suggesting that she might have preferred an even smaller size under the CD gloves. One male subject wore the largest Nomex size (#11) both over and under the CD gloves. Two prospective male subjects had been turned away after the size 11 Nomex gloves proved to be too tight. This suggests that additional sizes of Nomex gloves might be desirable in order to accommodate the flying population.

## The Tests

Five dexterity tests were used to evaluate the gloves:

- Minnesota Rate of Manipulation Turning Test
- O'Connor Finger Dexterity Test
- Pennsylvania Bi-Manual Worksample--Assembly
- Roeder Manipulative Aptitude Test--Rods and Caps
- Purdue Pegboard Assembly Test

Of these, three (the Minnesota, O'Connor and Pennsylvania tests) had been used in a previous study of gloves (Robinette et al., 1986), and two (Purdue and




| | 16.8 | 17.0 | 17.2 | 17.4 | 17.6 | 17.8 | 18.0 | 18.2 | 18.4 | 18.6 | 18.8 | 19.0 | 19.2 | 19.4 | 19.6 | 19.8 | 20.0 | 20.2 | 20.4 | 20.6 | 20.8 | 21.0 | 21.2 | 21.4 | 21.6 | 21.8 | 22.0 | 22.2 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.2 | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | | | | 1 | | 3 |
| 10.1 | | | | | | | | | | | | | | | 1 | | 2 | | | | 1 | | 1 | | 1 | | | | 6 |
| 10.0 | | | | | | | | | | | | 1 | | 1 | 1 | 1 | | 2 | 1 | 2 | 1 | | 3 | | | | | | 13 |
| 9.9 | | | | | | | | | | | 1 | 1 | | | 1 | 2 | 2 | | 2 | 4 | 2 | 1 | | | | | | | 16 |
| 9.8 | | | | | | | | | | | | | | 1 | 2 | 1 | 2 | 2 | 3 | 4 | | 1 | 1 | | | 1 | 1 | | 19 |
| 9.7 | | | | | | | | 1 | | | 1 | 1 | 3 | 2 | 6 | 5 | 3 | 6 | 3 | 1 | 4 | | 2 | | 1 | | | | 39 |
| 9.6 | | | | | | | 1 | | 1 | 1 | 1 | 1 | 4 | 2 | 6 | 8 | | 5 | 12 | 5 | 2 | 2 | 3 | 1 | 1 | | | | 55 |
| 9.5 | | | | 1 | | 11 | | | | 1 | 5 | 3 | 7 | 10 | 7 | 6 | 14 | 10 | 6 | 8 | 3 | 3 | | | | 1 | | | 85 |
| 9.4 | | | | | | | | | 4 | 5 | 3 | 7 | 11 | 17 | 13 | 10 | 13 | 7 | 9 | 6 | 1 | 1 | 2 | 1 | | | | | 110 |
| 9.3 | | | | | | 2 | 1 | 2 | 5 | 2 | 11 | 10 | 12 | 12 | 14 | 9 | 7 | 10 | 12 | 3 | 2 | 2 | 1 | | | | | | 117 |
| 9.2 | | | | | 1 | | | 3 | 8 | 16 | 8 | 16 | 9 | 27 | 25 | 16 | 17 | 8 | 13 | 8 | 9 | 3 | 4 | 2 | | | | 1 | 185 |
| 9.1 | 1 | | | | | 1 | | 10 | 8 | 8 | 11 | 23 | 22 | 29 | 31 | 27 | 15 | 16 | 15 | 12 | 14 | 2 | 2 | | 1 | | | | 228 |
| 9.0 | | | | | | 9 | 1 | 5 | 6 | 11 | 13 | 16 | 26 | 22 | 16 | 11 | 24 | 7 | 11 | 6 | 4 | 1 | 1 | 1 | | | | | 178 |
| 8.9 | | | 2 | 2 | 2 | 6 | 8 | 12 | 16 | 25 | 34 | 29 | 29 | 30 | 30 | 21 | 11 | 9 | 6 | 3 | 4 | 1 | | | | | | | 280 |
| 8.8 | | | 3 | 2 | 4 | 1 | 12 | 14 | 25 | 13 | 21 | 23 | 24 | 18 | 24 | 12 | 5 | 3 | 1 | 2 | 2 | | | | | | | | 209 |
| 8.7 | | | 1 | 4 | 11 | 4 | 8 | 5 | 9 | 22 | 19 | 20 | 19 | 19 | 27 | 11 | 13 | 5 | 5 | 3 | 1 | | | | | | | | 200 |
| 8.6 | 1 | 1 | 3 | 3 | 5 | 9 | 14 | 13 | 11 | 21 | 19 | 11 | 23 | 25 | 15 | 8 | 3 | 1 | 6 | 4 | 1 | 1 | | | | | | | 200 |
| 8.5 | | | | 1 | 6 | 10 | 7 | 12 | 14 | 20 | 16 | 15 | 14 | 9 | 6 | 4 | 4 | 2 | | 2 | | 1 | | | | | | | 143 |
| 8.4 | | | 4 | 1 | 3 | 8 | 12 | 11 | 14 | 19 | 10 | 13 | 8 | 7 | 10 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | | | | | | | 122 |
| 8.3 | 2 | | 3 | 1 | 4 | 2 | 6 | 12 | 9 | 13 | 8 | 7 | 6 | 2 | 2 | 1 | 1 | 2 | | | | | | | | | | | 81 |
| 8.2 | | | | 3 | 4 | 10 | 1 | 9 | 7 | 2 | 6 | 6 | 8 | 1 | 7 | 2 | 1 | 1 | 1 | | | | | | | | | | 59 |
| 8.1 | | | | 4 | 4 | | 2 | 2 | 7 | 4 | 5 | 2 | 3 | 2 | 2 | 1 | 1 | | | | | | | | | | | | 39 |
| 8.0 | 1 | | | | 1 | | 1 | 1 | 1 | 2 | 1 | | 1 | | | 1 | | | | | | | | | | | | | 10 |
| 7.9 | | | | 1 | 1 | 2 | 1 | | | 1 | 1 | 2 | 1 | | 1 | | | | | | | 1 | | | | | | | 12 |
| 7.8 | | | 1 | | 2 | 2 | | 1 | | 2 | 1 | | | | | | | | | | | | | | | | | | 9 |
| 7.7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7.6 | | | | 9 | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | 2 |
| TOTAL | 5 | 1 | 17 | 23 | 41 | 53 | 85 | 123 | 177 | 188 | 224 | 220 | 239 | 239 | 209 | 141 | 109 | 104 | 87 | 58 | 30 | 20 | 15 | 4 | 3 | 2 | 2 | 1 | 2420 |

Figure 4. Outer Nomex sizes of male test subjects superimposed on a bivariate frequency table for hand length and hand breadth of 1967 USAF male flying personnel.

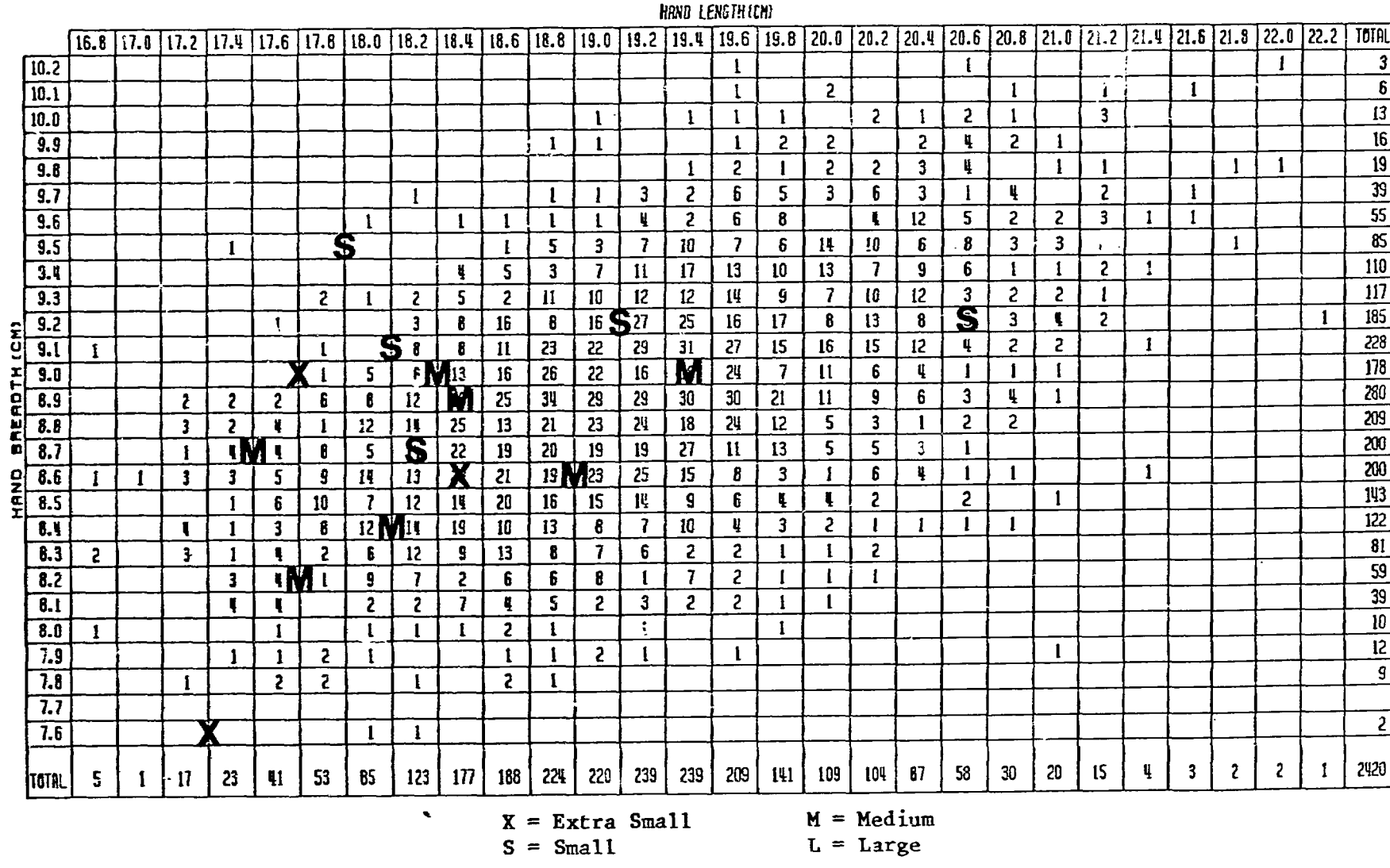
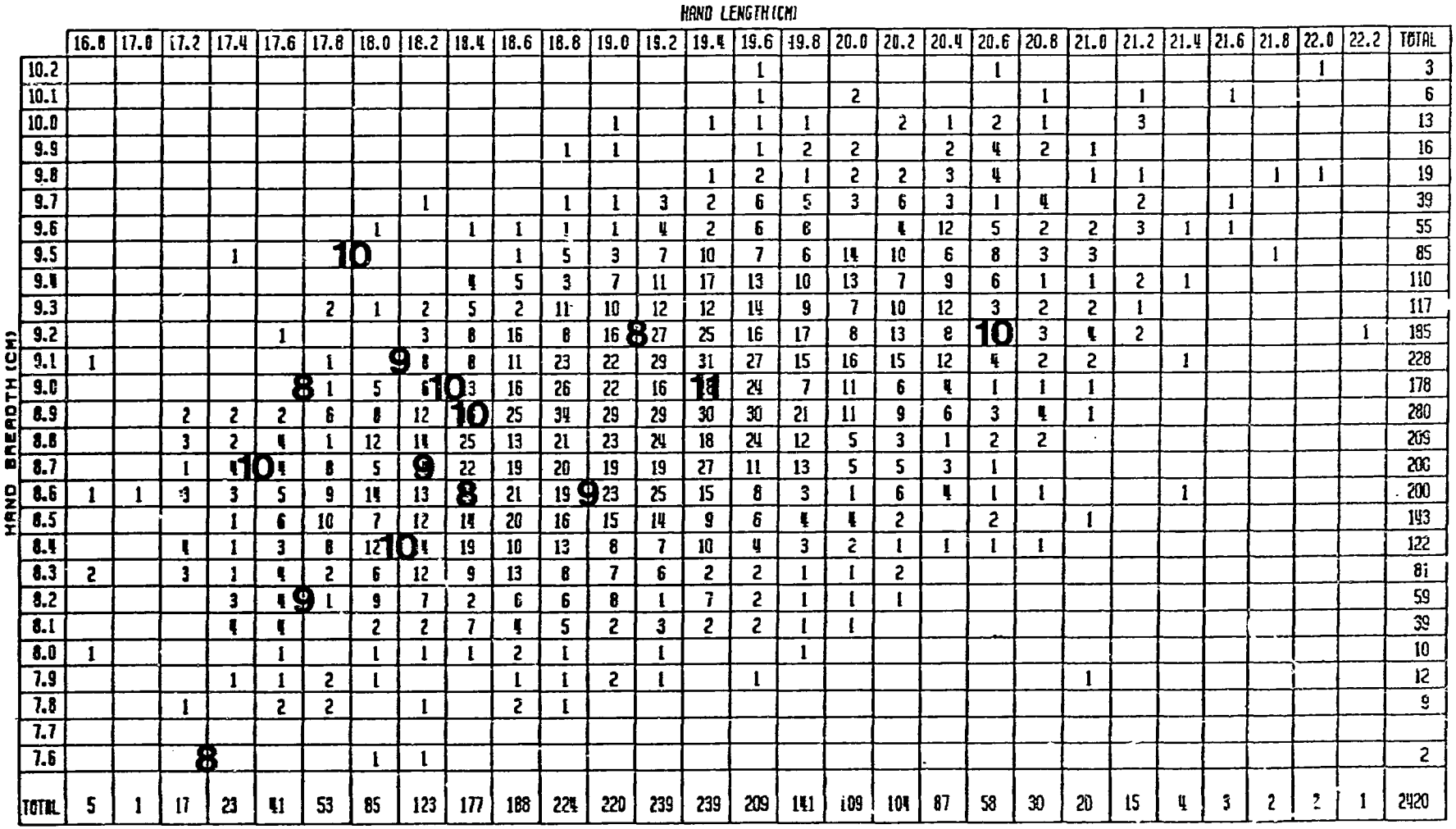



Figure 5. Chemical defense glove sizes of male test subjects superimposed on a bivariate frequency table for hand length and hand breadth of 1967 USAF male flying personnel.




| | 16.6 | 17.0 | 17.2 | 17.4 | 17.6 | 17.8 | 18.0 | 18.2 | 18.4 | 18.6 | 18.8 | 19.0 | 19.2 | 19.4 | 19.6 | 19.8 | 20.0 | 20.2 | 20.4 | 20.6 | 20.8 | 21.0 | 21.2 | 21.4 | 21.6 | 21.8 | 22.0 | 22.2 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.2 | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | | | | 1 | | 3 |
| 10.1 | | | | | | | | | | | | | | | 1 | | 2 | | | | 1 | | 1 | | 1 | | | | 6 |
| 10.0 | | | | | | | | | | | | 1 | | 1 | 1 | 1 | | 2 | 1 | 2 | 1 | | 3 | | | | | | 13 |
| 9.9 | | | | | | | | | | | 1 | 1 | | | 1 | 2 | 2 | | 2 | 4 | 2 | 1 | | | | | | | 16 |
| 9.8 | | | | | | | | | | | | | | 1 | 2 | 1 | 2 | 2 | 3 | 4 | | 1 | 1 | | | 1 | 1 | | 19 |
| 9.7 | | | | | | | | 1 | | | 1 | 1 | 3 | 2 | 6 | 5 | 3 | 6 | 3 | 1 | 4 | | 2 | | 1 | | | | 39 |
| 9.6 | | | | | | | 1 | | 1 | 1 | 1 | 1 | 4 | 2 | 6 | 6 | | 4 | 12 | 5 | 2 | 2 | 3 | 1 | 1 | | | | 55 |
| 9.5 | | | | 1 | | | | | | 1 | 5 | 3 | 7 | 10 | 7 | 6 | 14 | 10 | 6 | 8 | 3 | 3 | | | | 1 | | | 85 |
| 9.4 | | | | | | | | | 4 | 5 | 3 | 7 | 11 | 17 | 13 | 10 | 13 | 7 | 9 | 6 | 1 | 1 | 2 | 1 | | | | | 110 |
| 9.3 | | | | | | 2 | 1 | 2 | 5 | 2 | 11 | 10 | 12 | 12 | 14 | 9 | 7 | 10 | 12 | 3 | 2 | 2 | 1 | | | | | | 117 |
| 9.2 | | | | | 1 | | | 3 | 8 | 16 | 8 | 16 | 27 | 25 | 16 | 17 | 8 | 13 | 8 | 10 | 3 | 4 | 2 | | | | | 1 | 185 |
| 9.1 | 1 | | | | | 1 | | 8 | 8 | 11 | 23 | 22 | 29 | 31 | 27 | 15 | 16 | 15 | 12 | 4 | 2 | 2 | | 1 | | | | | 228 |
| 9.0 | | | | | | 1 | 5 | 6 | 3 | 16 | 26 | 22 | 16 | 11 | 24 | 7 | 11 | 6 | 4 | 1 | 1 | 1 | | | | | | | 178 |
| 8.9 | | | 2 | 2 | 2 | 6 | 8 | 12 | 10 | 25 | 34 | 29 | 29 | 30 | 30 | 21 | 11 | 9 | 6 | 3 | 4 | 1 | | | | | | | 280 |
| 8.8 | | | 3 | 2 | 4 | 1 | 12 | 14 | 25 | 13 | 21 | 23 | 24 | 18 | 24 | 12 | 5 | 3 | 1 | 2 | 2 | | | | | | | | 209 |
| 8.7 | | | 1 | 4 | 4 | 8 | 5 | 9 | 22 | 19 | 20 | 19 | 19 | 27 | 11 | 13 | 5 | 5 | 3 | 1 | | | | | | | | | 200 |
| 8.6 | 1 | 1 | 3 | 3 | 5 | 9 | 14 | 13 | 8 | 21 | 19 | 23 | 25 | 15 | 8 | 3 | 1 | 6 | 4 | 1 | 1 | | | 1 | | | | | 200 |
| 8.5 | | | | 1 | 6 | 10 | 7 | 12 | 14 | 20 | 16 | 15 | 14 | 9 | 6 | 4 | 4 | 2 | | 2 | | 1 | | | | | | | 143 |
| 8.4 | | | 4 | 1 | 3 | 8 | 12 | 10 | 4 | 19 | 10 | 13 | 8 | 7 | 10 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | | | | | | | 122 |
| 8.3 | 2 | | 3 | 1 | 4 | 2 | 6 | 12 | 9 | 13 | 8 | 7 | 6 | 2 | 2 | 1 | 1 | 2 | | | | | | | | | | | 81 |
| 8.2 | | | | 3 | 4 | 1 | 9 | 7 | 2 | 6 | 6 | 8 | 1 | 7 | 2 | 1 | 1 | 1 | | | | | | | | | | | 59 |
| 8.1 | | | | 4 | 4 | | 2 | 2 | 7 | 4 | 5 | 2 | 3 | 2 | 2 | 1 | 1 | | | | | | | | | | | | 39 |
| 8.0 | 1 | | | | 1 | | 1 | 1 | 1 | 2 | 1 | | 1 | | | 1 | | | | | | | | | | | | | 10 |
| 7.9 | | | | 1 | 1 | 2 | 1 | | | 1 | 1 | 2 | 1 | | 1 | | | | | | | 1 | | | | | | | 12 |
| 7.8 | | | 1 | | 2 | 2 | | 1 | | 2 | 1 | | | | | | | | | | | | | | | | | | 9 |
| 7.7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7.6 | | | | 8 | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | 2 |
| TOTAL | 5 | 1 | 17 | 23 | 41 | 53 | 85 | 123 | 177 | 188 | 224 | 220 | 239 | 239 | 209 | 141 | 109 | 104 | 87 | 58 | 30 | 20 | 15 | 4 | 3 | 2 | 2 | 1 | 2420 |

Figure 6. Inner Nomex sizes of male test subjects superimposed on a bivariate frequency table for hand length and hand breadth of 1967 USAF male flying personnel.

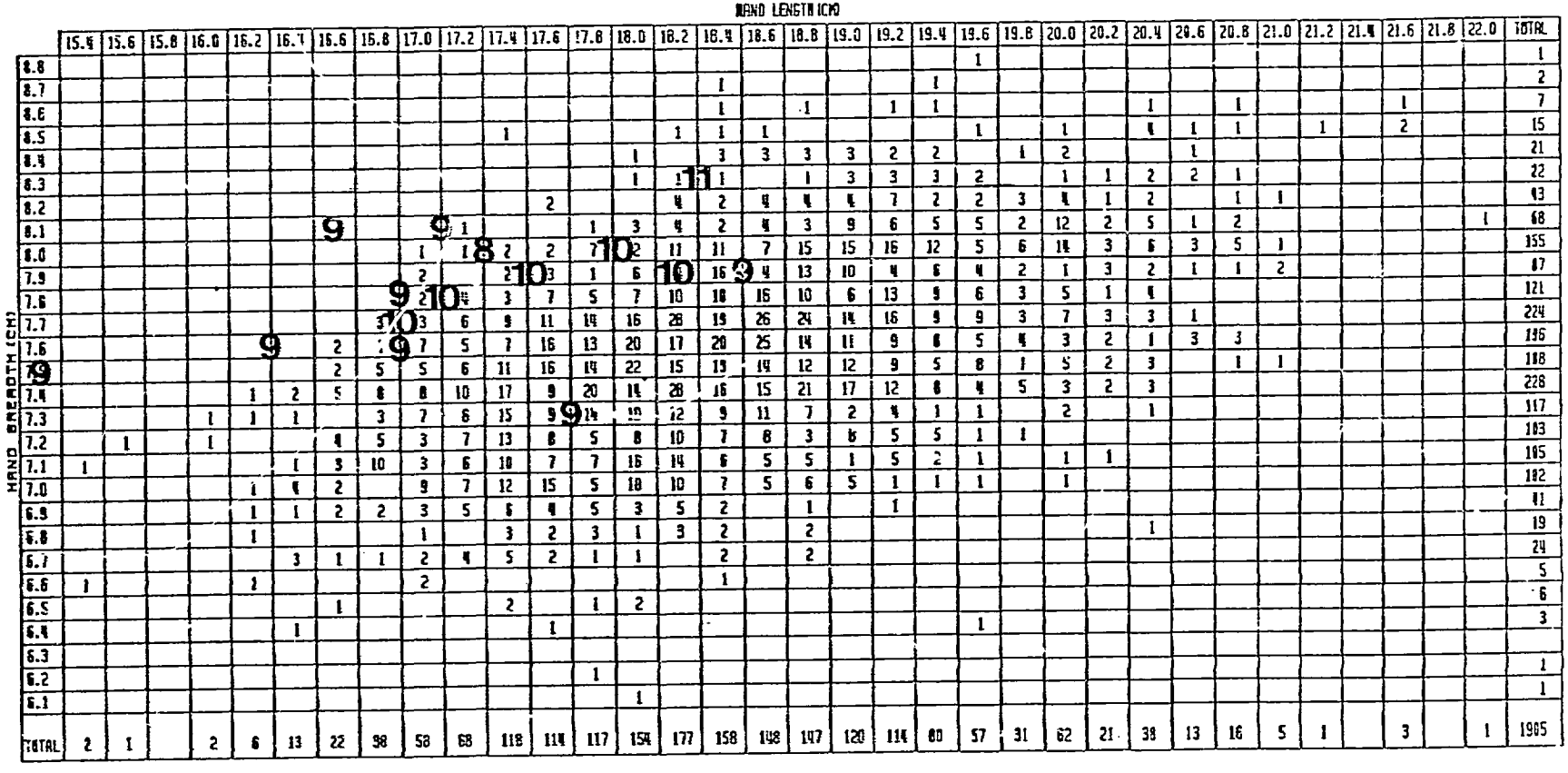



Figure 7. Outer Nomex sizes of female test subjects superimposed on a bivariate frequency table for hand length and hand breadth of 1968 USAF women.

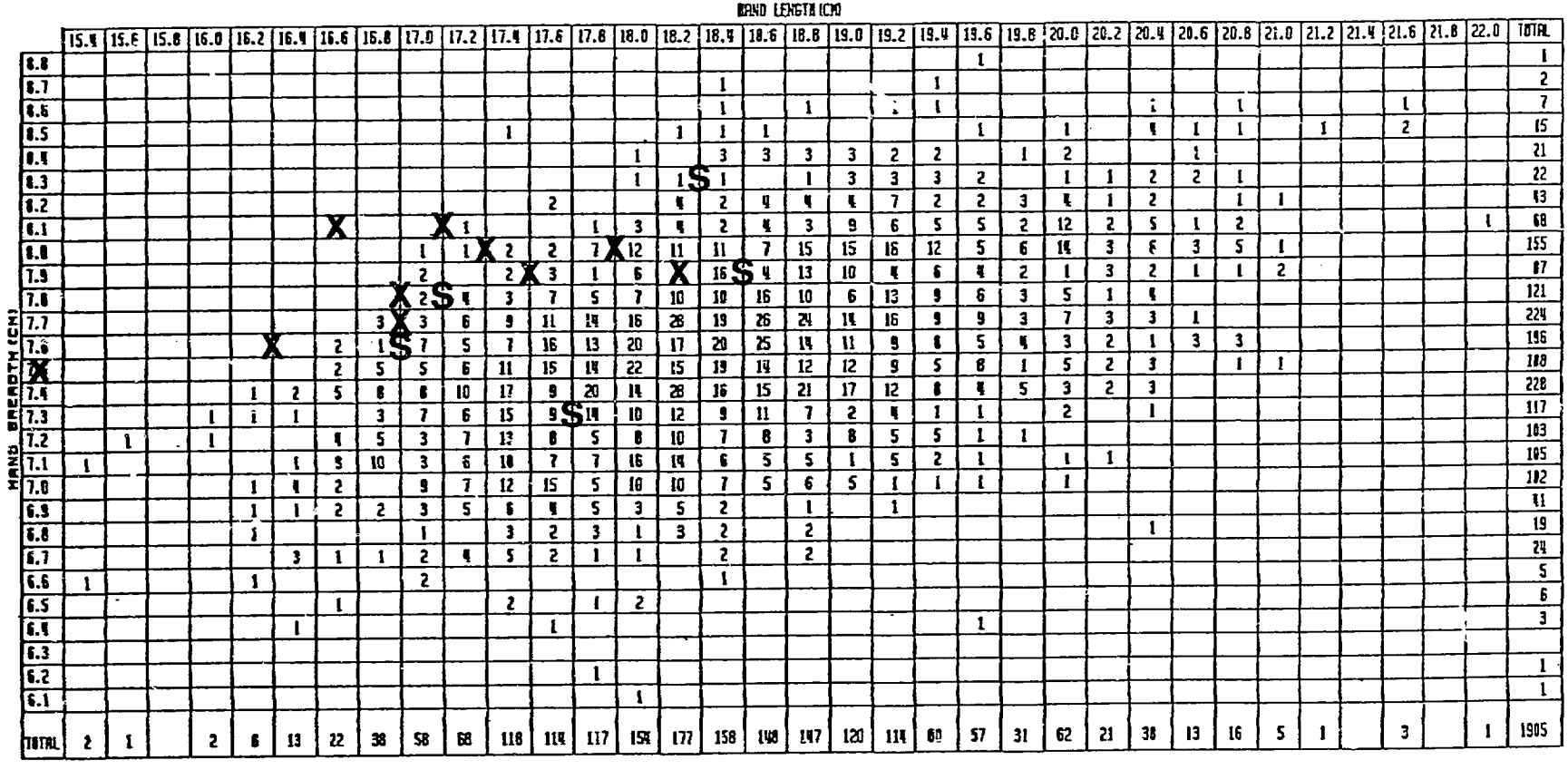



Figure 8. Chemical defense glove sizes of female test subjects superimposed on a bivariate frequency table for hand length and hand breadth of 1968 USAF women.

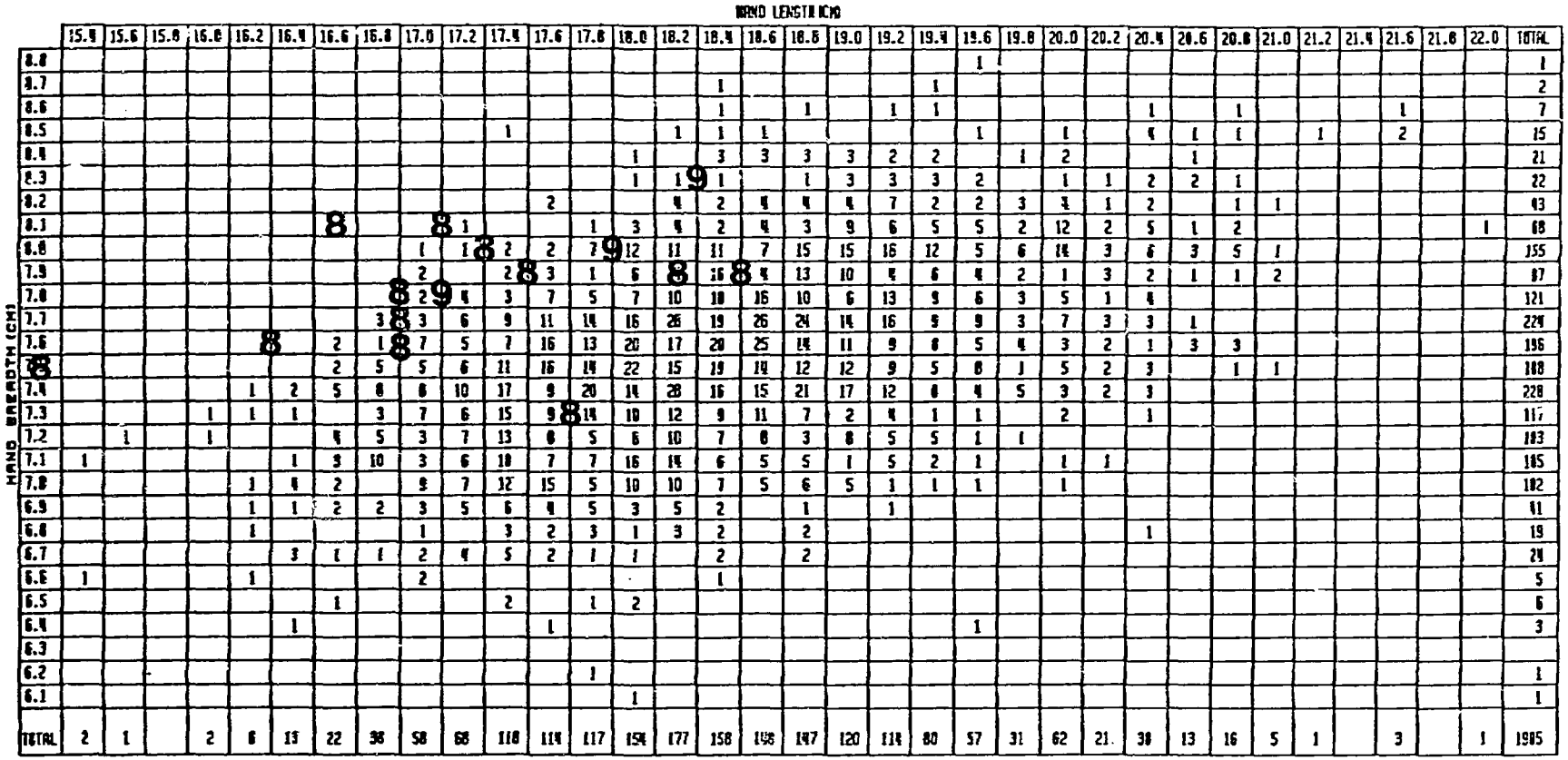



Figure 9. Inner Nomex sizes of female test subjects superimposed on a bivariate frequency table for hand length and hand breadth of 1968 USAF women.

Roeder) were found to be sensitive to differences between glove types in preliminary testing for this study. In previous studies, all tests proved to discriminate between such different glove types as 25 mil and 14 mil butyl gloves, with the use of samples as small as 30.

The tests are described below, along with modifications made for glove-testing purposes. Instructions given to the subjects are included in Appendix B.

The Minnesota Rate of Manipulation Turning test (Figure 10) is a two-handed test performed with the subject standing up. The object is to turn blocks over as quickly as possible, picking them up with one hand and putting them down bottom side up with the other hand. This test is scored by completion time and was not modified.

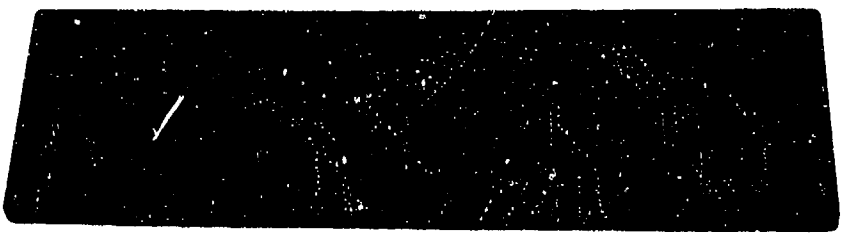


Figure 10. Minnesota Rate of Manipulation Test.

The Roeder Manipulative Aptitude Test--Rods and Caps (Figure 11) is performed with the dominant hand. The subject is seated. Rods of approximately two centimeters in length are screwed into rows of sockets which are evenly spaced, approximately three centimeters apart, on the test board. Test instructions originally called for scoring by the number of rods and the number of caps placed in three minutes. For this study the time was shortened to two minutes, which decreased subject boredom and frustration, but retained

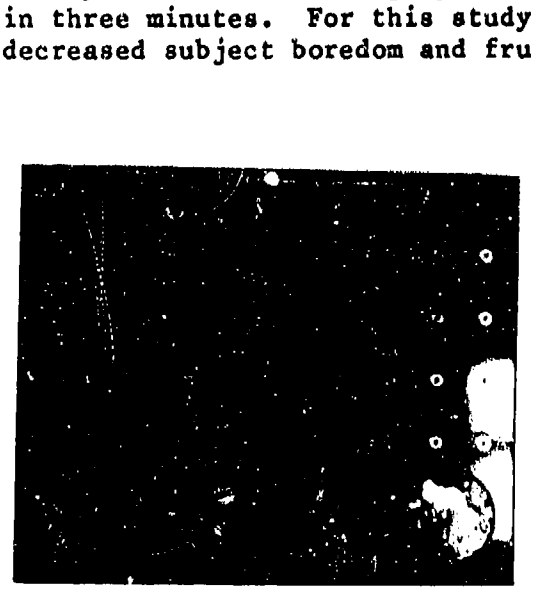


Figure 11. The Roeder Manipulative Aptitude Test.

sensitivity to differences between glove types. Practice trials were one minute in length. Scoring was simplified to a single number representing the total number of pieces placed.

In the Purdue Pegboard Assembly Test (Figure 12) the subject uses both hands to build assemblies of pins, washers, and collars. Both right-handed and left-handed subjects perform the test the same way. The test was scored by the number of pieces successfully assembled in one minute. One complete assembly counted as four points; if the subject's last assembly was incomplete, one, two, or three points were awarded for portions completed. Once completed, an assembly counted for four points even if, as sometimes happened, the subject inadvertently knocked the top washer off. Practice trials lasted one minute.

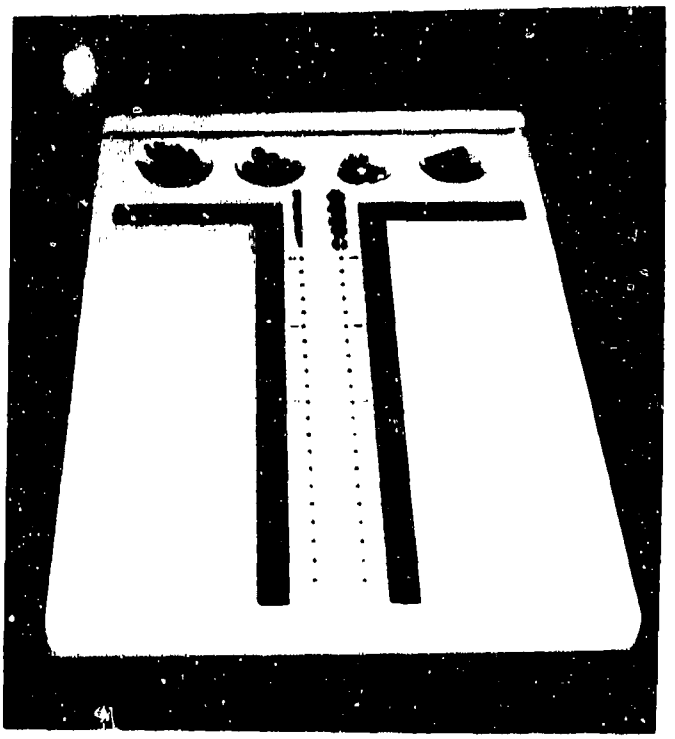


Figure 12. The Purdue Pegboard Assembly Test.

The O'Connor Finger Dexterity Test (Figure 13) is a one-handed test for the dominant hand in which the subject picks up three pins at a time and inserts them into one hole. The test board has 10 rows of 10 holes each. Originally, the test board was placed in front of the subject parallel to the edge of the table, so that the tray of pins was close to the subject's dominant hand. The subject was permitted to angle the board if desired. Test scores were recorded separately for the length of time required to fill the first 50 holes and the time required for the second 50 holes; these scores were later combined according to the formula:

$$\frac{(1.1)\ (\text{second-half time}) + (\text{first-half time})}{2} = \text{score}$$

to produce the total score. To simplify administration and reduce subject frustration, scores for this study were recorded as the number of holes filled with three pins in two minutes. Practice runs lasted one minute each. The position of the test apparatus was changed so that both left-handed and right-handed subjects took the test with the tray at the top of the board, and the long edges of the board perpendicular to the edge of the table in front of the subject. Subjects were not permitted to turn the board.

Figure 13. The O'Connor Finger Dexterity Test.

In the Pennsylvania Bi-Manual Worksample Assembly Test (Figure 14) the subject picks up a bolt with the dominant hand and a nut with the other hand, then puts the nut and bolt together and places the assembled unit in a hole. The board contains 10 rows of 10 holes each. The original test instructions provide for two rows of practice, with the subject completing rows three through ten for an actual test; the subject's score is the length of time required to finish the last eight rows. For this study scoring was changed to the number of assemblies placed during a two-minute period. Subjects were allowed one minute for each practice run.

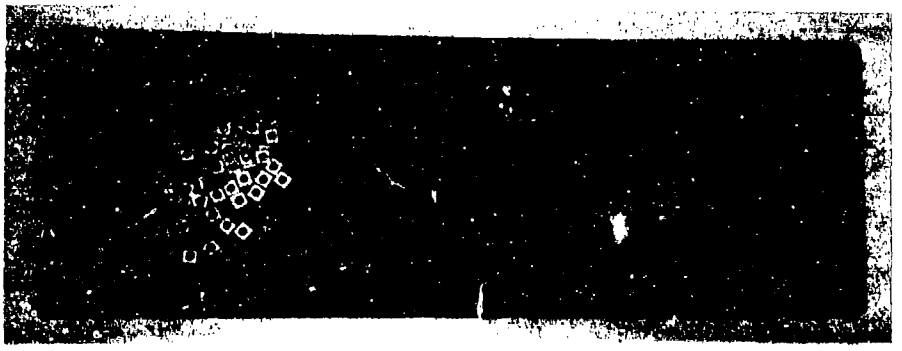


Figure 14. The Pennsylvania Bi-Manual Worksample.

Procedures

The tests were given in two sessions. During session one, subjects performed the three shorter tests (Minnesota, Roeder, and Purdue). During session two, subjects performed the two longer tests (O'Connor and Pennsylvania). This arrangement kept each session to a little under three hours in length. Breaks were provided between tests and whenever a subject became tired or requested one. Each subject completed all tests in two sessions. Although no subject completed both sessions on the same day, the time between sessions was not thought to affect the outcome since practices for given tests were completed in the same session as the test.

Subjects were run two at a time by two different investigators. They were encouraged to compete with each other to increase their motivation, and to do their best while maintaining the proper techniques.

Verbal instructions for each test, accompanied by a brief demonstration, were given to each subject before practice began. During practice trials, instruction was given, if needed, to ensure that the test was performed correctly.

To reduce the effect of learning on the relative scores for the gloves, each subject performed six practice trials for each test. The practice trials covered the gamut of gloved conditions subjects would experience in the tests: bare-handed, double-layered, and triple-layered. Six practices were enough to ensure that the subject mastered each test (Robinette et al., 1986) but not so many that they became bored before data collection began. The practices were run consecutively under three conditions: first, two trials without gloves, then two trials wearing Nomex under B7, and lastly two trials wearing liner, EB 12.5, and Nomex. Presenting practice trials in order of increasing difficulty (in terms of glove thickness and number of layers) is believed to enhance learning (personal communication, Dr. Dan Fisk, Wright State University Symposium, February 12, 1985).

Practices for all five of the tests were run in the same order, under the same conditions. All practice trials lasted one minute, except practice trials for the brief Minnesota test which were shorter.

Following the practice trials the subjects performed each test three times for each of five conditions. Figure 15 is a sample data sheet which illustrates the ordering for one subject. A subject given this sheet would first complete the practice trials, then perform the Roeder MAT Test--Rods and Caps three times with no gloves, then the Purdue Assembly test three times wearing the Nomex/EB 12.5 combination, and so on. The next subject would have a different, randomly selected order to follow, which would be listed on the next data sheet.

Conditions were randomized so that no one condition would be repeatedly performed first or last and so be consistently affected by any remaining learning, boredom, or other effects.

## RESULTS

### Data Analysis

The mean of each subject's scores on his or her last two trials was used for data analysis. This helped to guard against the effects of anomalous scores.

Tables 4 through 8 and Figures 16 through 20 show the results of Analysis of Variance (ANOVA) procedures run separately on the results of each dexterity test. These analyses show that none of the five tests indicated an interaction between the effects of glove combination and the sex of the subject ($\alpha = .01$).

It may be concluded that the combination of gloves worn does not adversely affect one sex more than the other.

Since there did not appear to be a significant interaction between sex and glove type, results were analyzed with the male and female samples combined.

Table 9 lists results of Duncan's Multiple Range Test procedures. In this table, glove ensembles are listed across the top and tests are listed in the left-most column. Within the table, mean scores for each ensemble for each test are shown. Below the means, the results of the Duncan test indicate whether the differences between the means are statistically significant. Means with the same letter are not significantly different ($\alpha = .05$) from each other. The results are reasonably consistent across all tests. Consequently, it is possible to list the ensembles left to right from best to worst.

All gloved conditions appear to be significantly worse than the bare-handed condition. Both of the three-layer ensembles (L/EB12.5/N and L/B7/N) appear to be significantly worse than the two-layer ensembles (L/EB12.5/N and L/B7/N) for four of the five tests. For the Minnesota test, these differences are large and apparent. Because this test is a fairly gross measure of dexterity which might be comparable to flipping a series of switches or turning a series of knobs to precise locations, the difference between the three- and two-layer ensembles is considered to be a very important one.

DEXTERITY EVALUATION OF AIRCREW GLOVES

Name _____ Handedness: ☐ Right ☐ Left

Subject No. _____ Glove Size _____

Sex: ☐ Male ☐ Female Liner Size _____

Age _____ Nomex Size _____

Date _____ Prior Testing _____

Anthropometry

| | | | |
|---|---|---|---|
| Hand Breadth | _____ | Digit 1 Circ | _____ |
| Crotch 1 Height | _____ | Digit 2 Circ Base | _____ |
| Crotch 2 Height | _____ | Digit 2 Circ Tip | _____ |
| Crotch 3 Height | _____ | Digit 3 Circ Base | _____ |
| Crotch 4 Height | _____ | Digit 3 Circ Tip | _____ |
| Digit 1 Length | _____ | | |
| Digit 2 Length | _____ | | |
| Hand Length | _____ | | |
| Digit 4 Length | _____ | | |
| Digit 5 Length | _____ | | |

1. What did you think of the glove fit? _____

_____

_____

2. Which type/combination was the most comfortable? _____

Uncomfortable? _____ Why? _____

_____

_____

3. Which glove type(s) do you think hindered your performance:

the least? _____ the most? _____

Comments _____

_____

_____

Figure 15. The data sheet.

| Minnesota (Timed) | Practice | | | Trials | | |
|---|---|---|---|---|---|---|
| No Gloves | | | 14 | | | |
| Nomex B-7 | | | 8 | | | |
| Liner EB-12.5 - Nomex | | | 12 | | | |
| Liner B-7 - Nomex | | | 11 | | | |
| Nomex EB-12.5 | | | 3 | | | |
| **MAT Rods & Caps (2 min.)** | | | | | | |
| No Gloves | | | 1 | | | |
| Nomex B-7 | | | 5 | | | |
| Liner EB-12.5 - Nomex | | | 15 | | | |
| Liner B-7 - Nomex | | | 7 | | | |
| Nomex EB-12.5 | | | 4 | | | |
| **Purdue Assembly (1 min.)** | | | | | | |
| No Gloves | | | 6 | | | |
| Nomex B-7 | | | 13 | | | |
| Liner EB-12.5 - Nomex | | | 10 | | | |
| Liner B-7 - Nomex | | | 9 | | | |
| Nomex EB-12.5 | | | 2 | | | |
| **O'Connor (2 min.)** | | | | | | |
| No Gloves | | | 2 | | | |
| Nomex B-7 | | | 10 | | | |
| Liner EB-12.5 - Nomex | | | 6 | | | |
| Liner B-7 - Nomex | | | 8 | | | |
| Nomex EB-12.5 | | | 5 | | | |
| **Pennsylvania (2 min.)** | | | | | | |
| No Gloves | | | 3 | | | |
| Nomex B-7 | | | 9 | | | |
| Liner EB-12.5 - Nomex | | | 7 | | | |
| Liner B-7 - Nomex | | | 1 | | | |
| Nomex EB-12.5 | | | 4 | | | |

Figure 15. (cont'd)

TABLE 4

SAS ANALYSIS OF VARIANCE STATISTICS FOR THE
PENNSYLVANIA BI-MANUAL WORKSAMPLE--ASSEMBLY

Dependent Variable: PENN

| Source | Degrees of Freedom | Mean Square | F Value | PR > F | R-Square | Covariance | Root Mean Square Error | PENN Mean |
|---|---|---|---|---|---|---|---|---|
| MODEL | 9 | 740.429 | 44.83 | 0.0001 | 0.7424 | 16.906 | 4.064 | 24.040 |
| ERROR | 140 | 16.517 | | | | | | |
| CORRECTED TOTAL | 149 | | | | | | | |

| Source | Degrees of Freedom | ANOVA SS | F Value | PR > F |
|---|---|---|---|---|
| SEX | 1 | [illegible]07 | 0.05 | 0.8254 |
| COMBINATION | 4 | 6653.377 | 100.70 | 0.0001 |
| SEX * COMBINATION | 4 | 9.677 | 0.15 | 0.9643 |

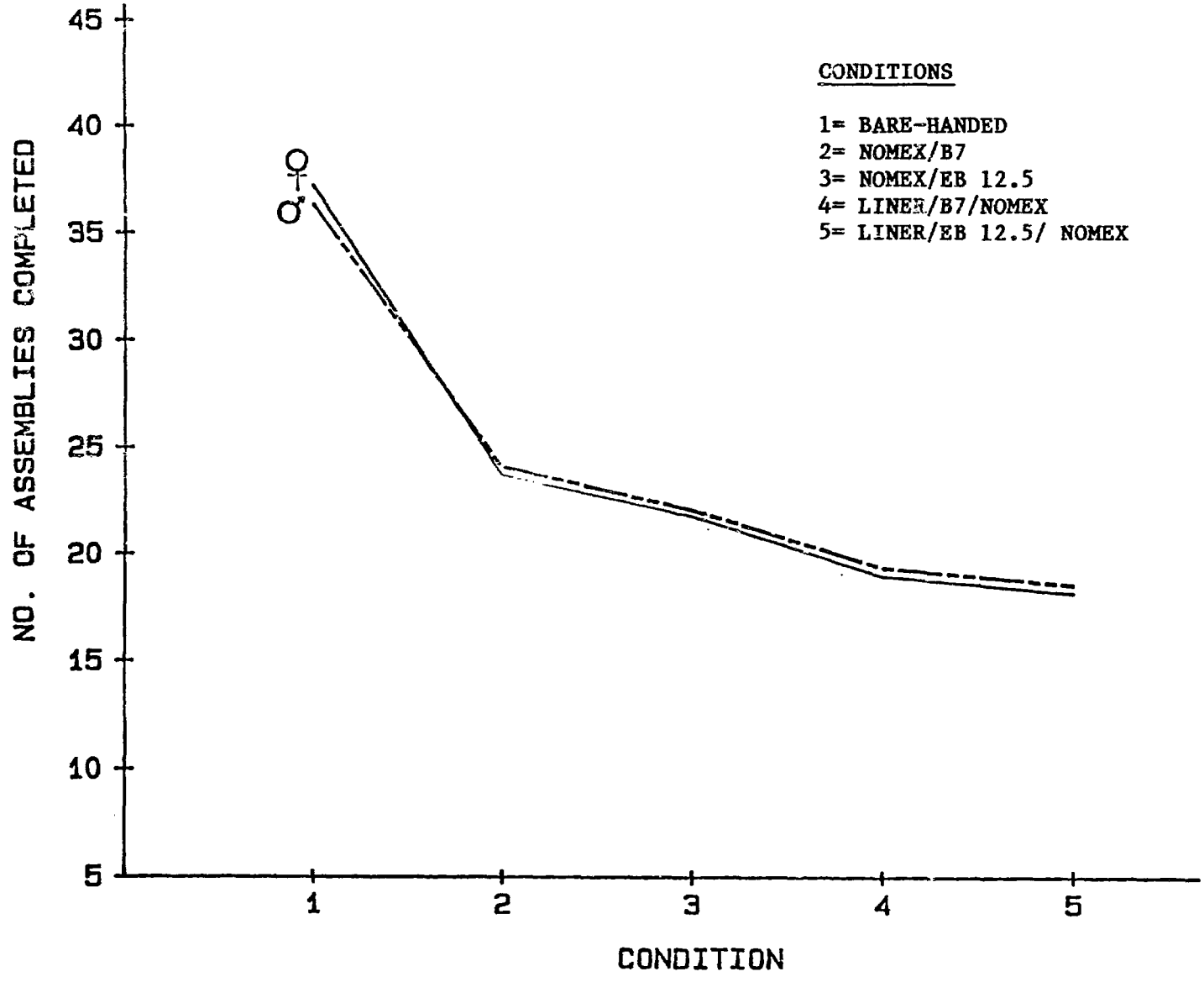



Figure 16. Mean scores of male and female subjects on the Pennsylvania Bi-Manual Worksample--Assembly.

TABLE 5

SAS ANALYSIS OF VARIANCE STATISTICS FOR THE MINNESOTA RATE OF MANIPULATION--TURNING TEST

Dependent Variable: MINN

| Source | Degrees of Freedom | Mean Square | F Value | PR > F | R-Square | Covariance | Root Mean Square Error | MINN Mean |
|---|---|---|---|---|---|---|---|---|
| MODEL | 9 | 843.963 | 20.55 | 0.0001 | 0.569 | 13.147 | 6.408 | 47.743 |
| ERROR | 140 | 41.066 | | | | | | |
| CORRECTED TOTAL | 149 | | | | | | | |

| Source | Degrees of Freedom | ANOVA SS | F Value | PR > F |
|---|---|---|---|---|
| SEX | 1 | 5.415 | 0.13 | 0.7171 |
| COMBINATION | 4 | 7497.993 | 45.65 | 0.0001 |
| SEX * COMBINATION | 4 | 92.260 | 0.56 | 0.6909 |

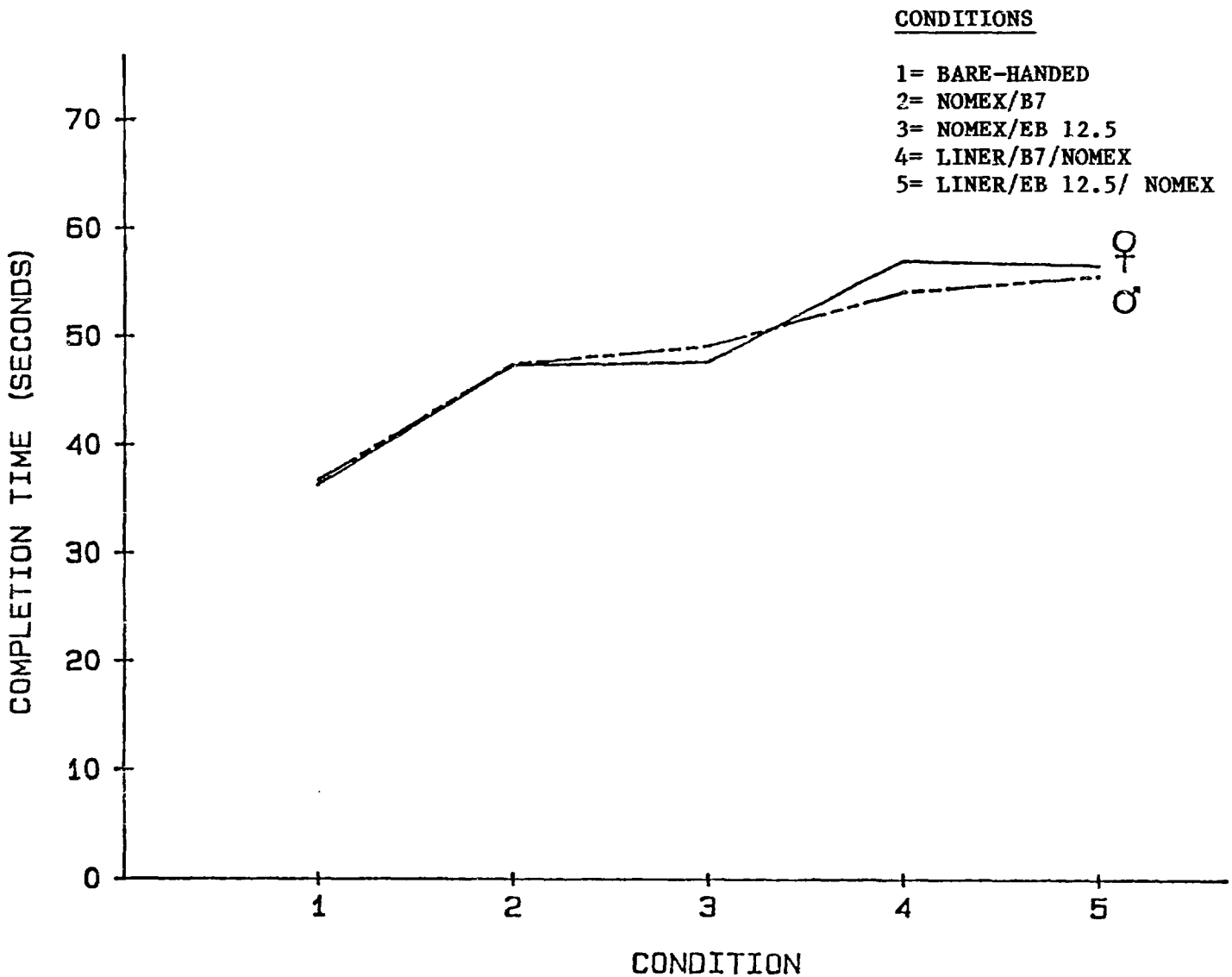



Figure 17. Mean scores of male and female subjects on the Minnesota Rate of Manipulation Test.

TABLE 6

SAS ANALYSIS OF VARIANCE STATISTICS FOR THE
ROEDER MANIPULATIVE APTITUDE TEST--RODS AND CAPS

Dependent Variable: MATRC

| Source | Degrees of Freedom | Mean Square | F Value | PR > F | R-Square | Covariance | Root Mean Square Error | MATRC Mean |
|---|---|---|---|---|---|---|---|---|
| MODEL | 9 | 1754.952 | 102.88 | 0.0001 | 0.86853 | 22.794 | 4.130 | 18.120 |
| ERROR | 140 | 17.059 | | | | | | |
| CORRECTED TOTAL | 149 | | | | | | | |

| Source | Degrees of Freedom | ANOVA SS | F Value | PR > F |
|---|---|---|---|---|
| SEX | 1 | 110.940 | 6.50 | 0.0118 |
| COMBINATION | 4 | 1[illegible].190 | 229.34 | 0.0001 |
| SEX * COMBINATION | 4 | 34.443 | 0.50 | 0.7323 |

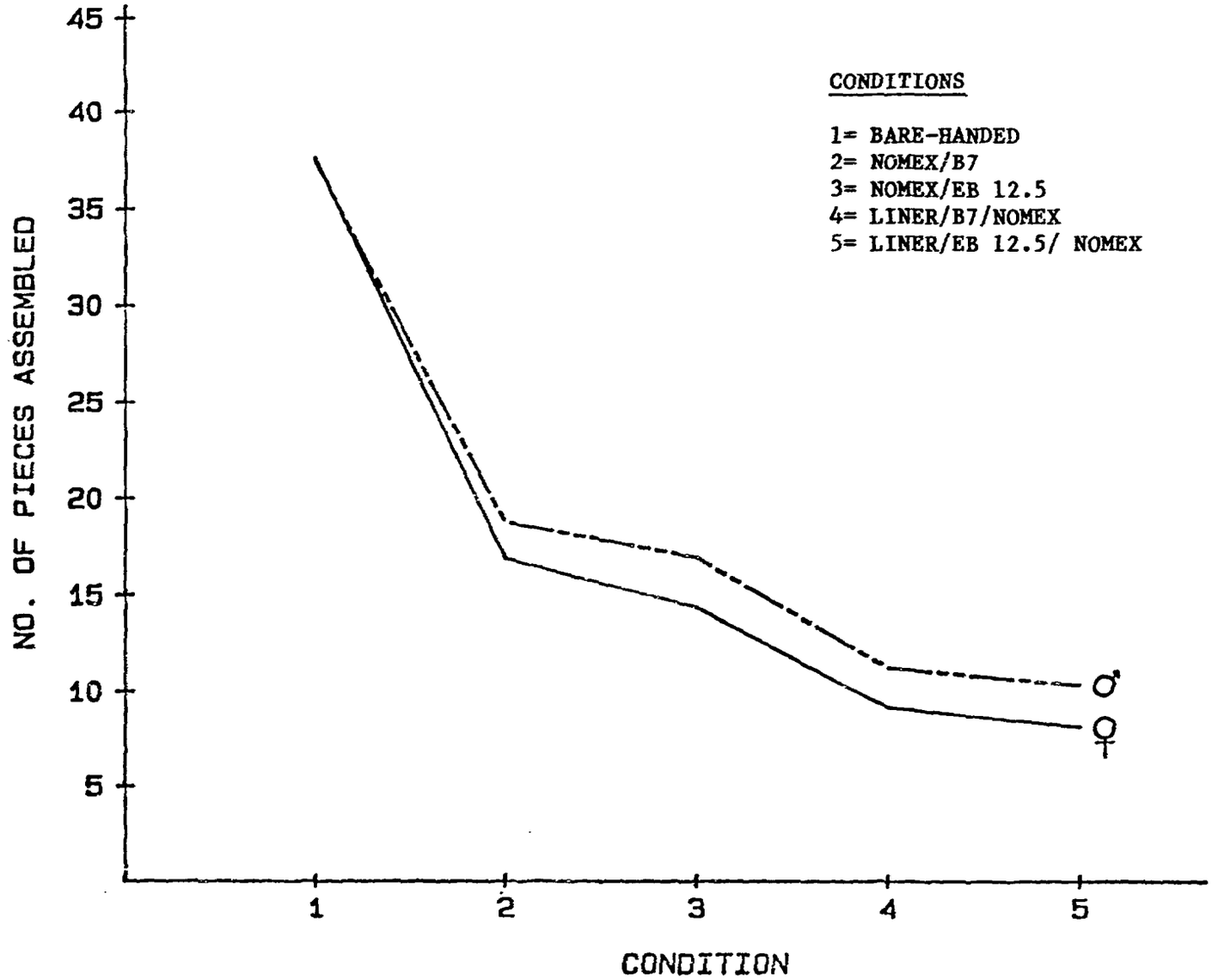



Figure 18. Mean scores of male and female subjects on the Roeder Manipulative Aptitude Test--Rods and Caps.

TABLE 7

SAS ANALYSIS OF VARIANCE STATISTICS FOR THE
O'CONNOR FINGER DEXTERITY TEST

Dependent Variable: OCON

| Source | Degrees of Freedom | Mean Square | F Value | PR > F | R-Square | Covar-iance | Root Mean Square Error | OCON Mean |
|---|---|---|---|---|---|---|---|---|
| MODEL | 9 | 335.610 | 22.930 | 0.0001 | 0.596 | 17.023 | 3.826 | 22.473 |
| ERROR | 140 | 14.635 | | | | | | |
| CORRECTED TOTAL | 149 | | | | | | | |

| Source | Degrees of Freedom | ANOVA SS | F Value | PR > F |
|---|---|---|---|---|
| SEX | 1 | 58.907 | 4.03 | 0.0468 |
| COMBINATION | 4 | 2933.493 | 50.11 | 0.0001 |
| SEX * COMBINATION | 4 | 28.093 | 0.48 | 0.7504 |

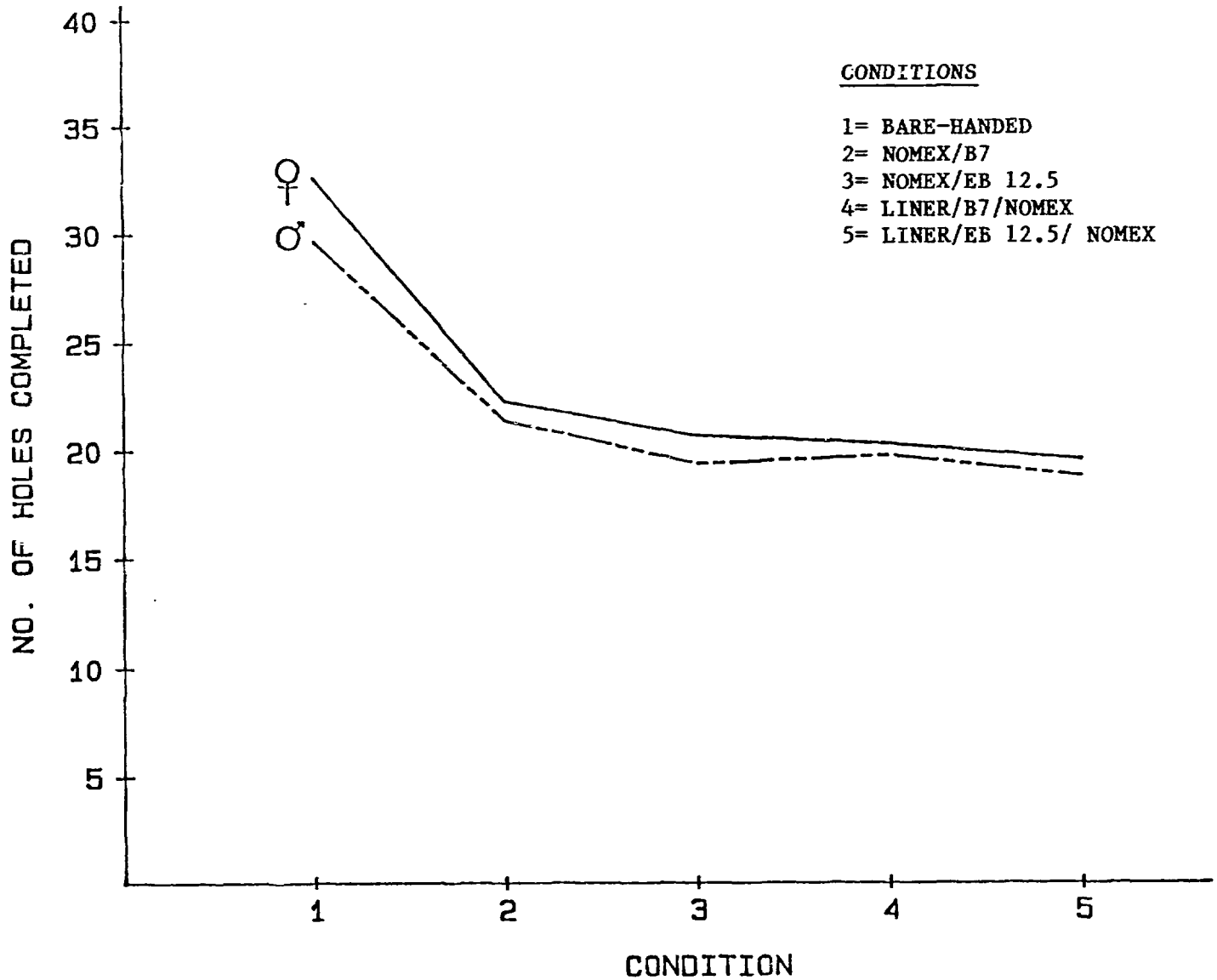



Figure 19. Mean scores of male and female subjects on the O'Connor Finger Dexterity Test.

TABLE 8

SAS ANALYSIS OF VARIANCE STATISTICS FOR THE
PURDUE PEGBOARD ASSEMBLY TEST

Dependent Variable: PASS

| Source | Degrees of Freedom | Mean Square | F Value | PR > F | R-Square | Covariance | Root Mean Square Error | PASS Mean |
|---|---|---|---|---|---|---|---|---|
| MODEL | 9 | 2796.120 | 134.04 | 0.0001 | 0.896 | 19.5991 | 4.567 | 23.303 |
| ERROR | 140 | 20.860 | | | | | | |
| CORRECTED TOTAL | 149 | | | | | | | |

| Source | Degrees of Freedom | ANOVA SS | F Value | PR > F |
|---|---|---|---|---|
| SEX | 1 | 44.282 | 2.12 | 0.1474 |
| COMBINATION | 4 | 24912.023 | 298.57 | 0.0001 |
| SEX * COMBINATION | 4 | 208.777 | 2.50 | 0.0451 |

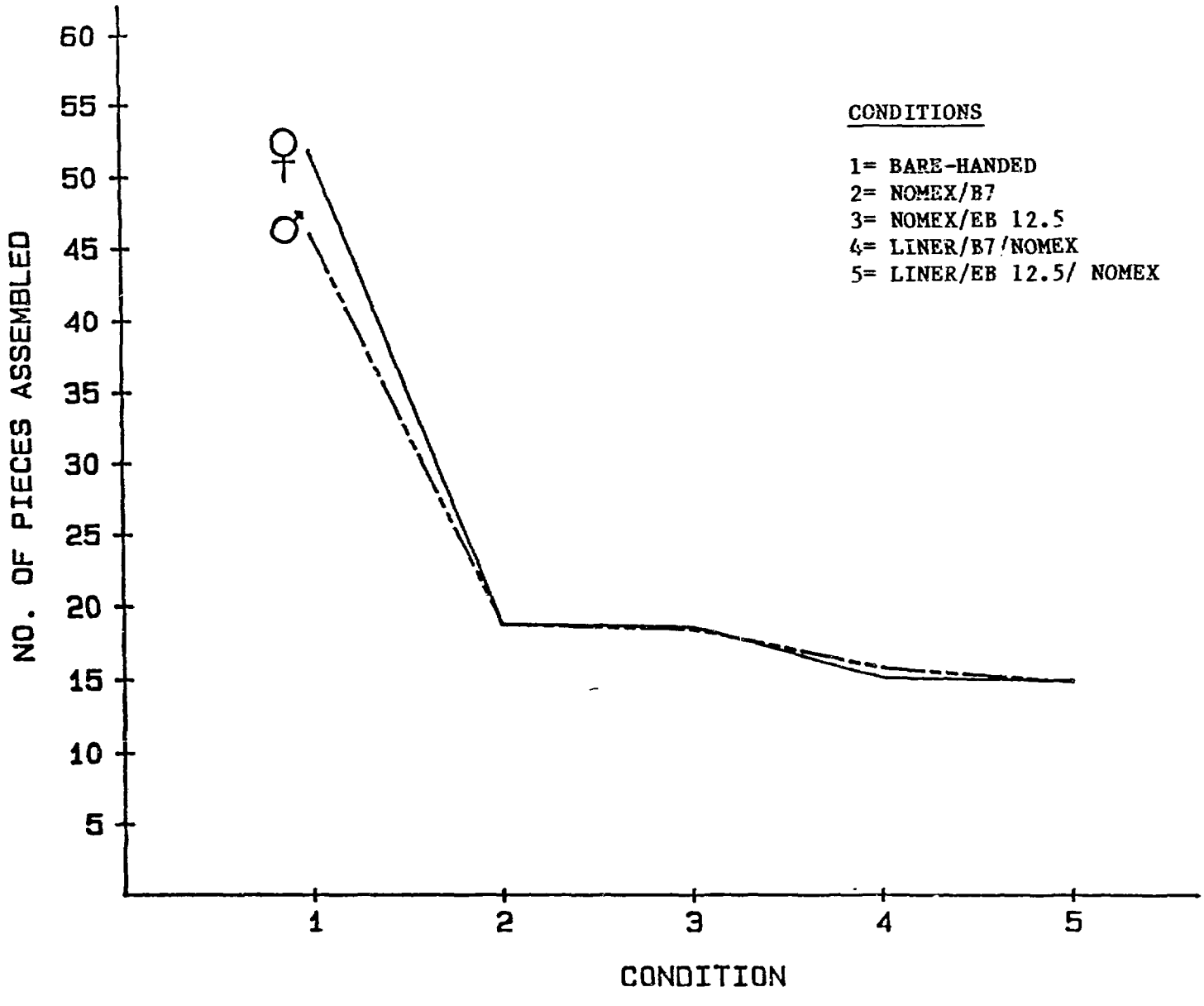



Figure 20. Mean scores of male and female subjects on the Purdue Pegboard Assembly Test.

TABLE 9

DUNCAN'S MULTIPLE RANGE TEST RESULTS
n=30

| Test | Bare-Handed | Nomex/B7 | Nomex/EB12.5 | L/B7/N | L/EB12.5/N |
|---|---|---|---|---|---|
| Minnesota: mean response (time in seconds) | 36.52 | 47.33 | 48.37 | 55.50 | 56.00 |
| Duncan | A | B | B | C | C |
| Rods and Caps: mean response (no. of pieces assembled in 2 min.) | 37.50 | 17.85 | 15.73 | 10.23 | 9.28 |
| Duncan | A | B | B | C | C |
| Purdue Assembly: mean response (no. of pieces assembled in 1 min.) | 48.88 | 18.80 | 18.52 | 15.47 | 14.85 |
| Duncan | A | B | B | C | C |
| O'Connor: mean response (no. of holes completed in 2 min.) | 31.15 | 21.85 | 20.08 | 20.07 | 19.22 |
| Duncan | A | B | BC | BC | C |
| Pennsylvania: mean response (no. of assemblies completed in 2 min.) | 36.77 | 23.90 | 21.95 | 19.20 | 18.38 |
| Duncan | A | B | B | C | C |

The remainder of the test scores are in terms of the average number of parts moved and placed or assembled. For example, in the Purdue Assembly test, bare-handed subjects were able, on the average, to assemble nearly 50 parts in the time allotted, but only about 15 while wearing the current Air Force CD glove ensemble. For this test, the statistically significant difference between the three-layer and two-layer ensembles appears to be rather insignificant from a practical point of view. However, the consistent pattern of differences for this and other tests demonstrates that differences between the glove types are real rather than figments of random variation. Even the O'Connor test results, which revealed little appreciable difference between the two- and three-layer glove ensembles, tended nevertheless to bear out the dominant trend.

## Glove Wear and Tear

The thicknesses of the CD gloves used for the study were measured, and all fell within the acceptable ranges. Each pair of gloves was returned to the bottom of its storage box after use. In this way no single pair of gloves of any size was used significantly more than the other pairs.

All CD gloves appeared worn after approximately 30 hours of use. Fingertips looked scuffed and slightly discolored. While none of the gloves wore through, seven butyl 7 gloves were torn during the course of the study. The tears occurred on the fingertips (Figures 21 and 22) and at the base of the thumb (Figure 23), in most cases on the dominant hand. The gloves tended to tear as the subjects pulled them on over the Nomex flight glove; however, two subjects "pinched" the fingertips between pieces of the Purdue Assembly test. One of the eco-butyl 12.5 gloves developed a pin-prick sized hole in the thumb tip which was discovered after testing.

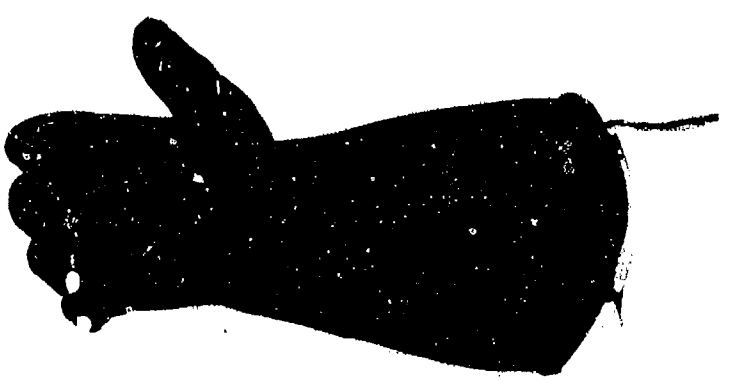


**Figure 21. Torn fingertips in butyl 7 CD glove.**

Figure 22. Torn index finger of butyl 7 CD glove.

Figure 23. Torn butyl 7 CD glove.

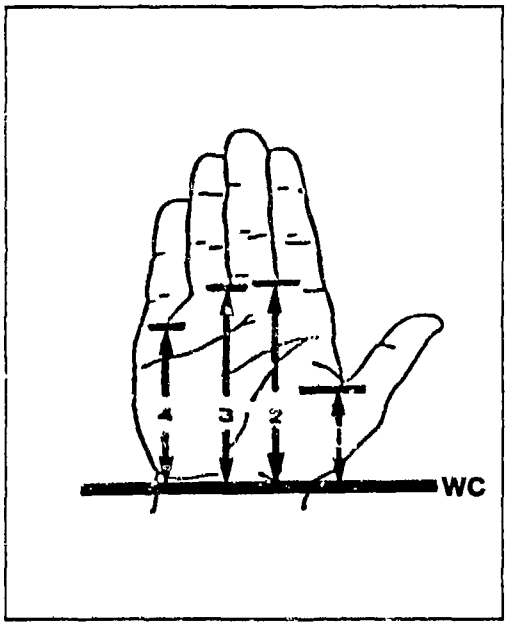
## CONCLUSIONS

While the results of this study seem to be intuitively obvious, it is the degree to which dexterity performance has been affected that is noteworthy. The two-layer combinations which consisted of Nomex underglove and CD overglove performed a great deal better than the three-layer ensembles which consisted of a cotton liner, CD glove and finally the Nomex overglove. Of the two-layer combinations, the 12.5 mil butyl ensemble is deemed best due to tearing problems with the 7 mil.

Dexterity and tactility performance with the Nomex-under-butyl combination might be further improved by removing the leather palm covering on the Nomex glove. This feature has no function when the Nomex glove is worn as a liner under the butyl CD glove.

## APPENDIX A

VISUAL INDEX OF
HAND DIMENSIONS

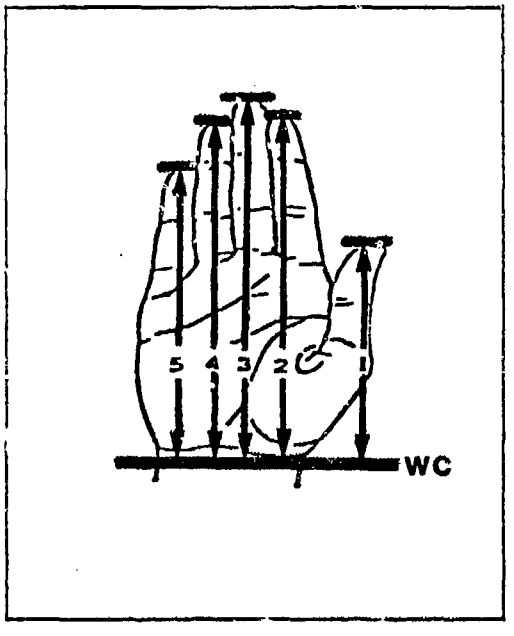



CROTCH HEIGHTS

With the fingers adducted and the thumb abducted, measure the perpendicular distance from the wrist crease baseline to the level of the hand crotches

Digit 5 was occasionally abducted to determine the correct location of the crotch prior to measuring.

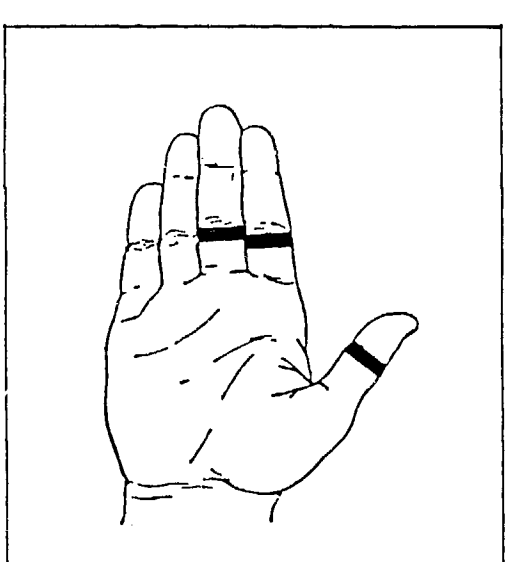
WC = wrist crease.




DIGIT LENGTHS

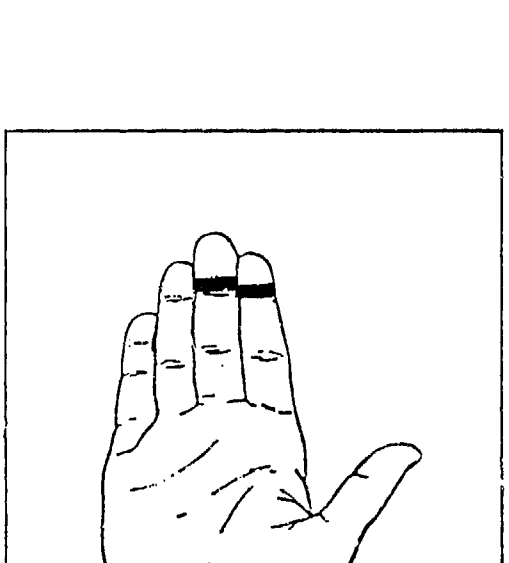
With the digits adducted, measure the perpendicular distance from the wrist crease baseline to the mid-point of the tip of each digit. Digit III Length is called Hand Length here.

WC = wrist crease.



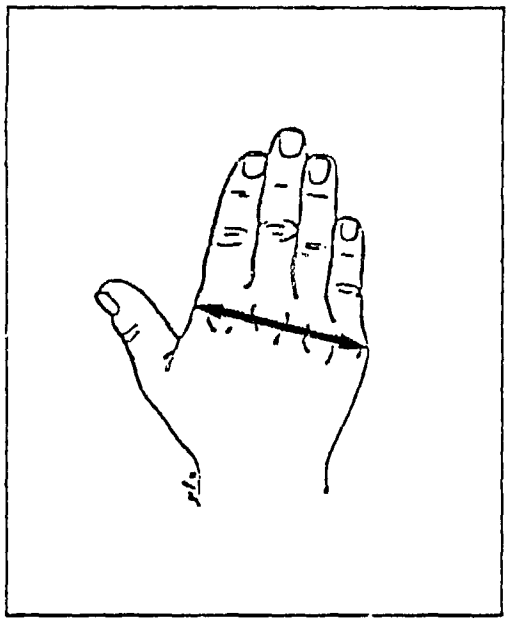
DIGIT CIRCUMFERENCE AT BASE

Subject's hand is extended, palm up. With the tape, measure the circumference of the digits at at the most proximal crease of the proximal interphalangeal joints II and III and the interphalangeal joint I.



DIGIT CIRCUMFERENCE AT TIP

Subject's hand is extended, palm up. With the tape, measure the circumference of the finger distal to the distal interphalangeal joint creases II and III.



HAND BREADTH

Subject's hand is extended, palm down, thumb held away from the fingers. With the bar of the sliding caliper lying across the back of the hand, measure the breadth of the hand between metacarpal-phalangeal joints II and V.

## APPENDIX B

GENERAL INSTRUCTIONS
FOR DEXTERITY TEST SUBJECTS

We are testing four combinations of gloves, which we will ask you to wear while performing a series of tests. You will also do the tests bare-handed. We are not testing how well you perform the tests, but rather the effects of the gloves on the tests, so we want you to do the tests as fast as you can, but we also would like your technique and speed to be as consistent as possible. In order for you to become familiar with the tests and the gloves, we will have you practice each test six times: twice without gloves, twice wearing these two gloves (indicate Nomex and butyl 7), and twice wearing these three gloves (indicate liner, eco-butyl 12.5 and Nomex). We will do all of the practice trials for today's tests before we actually collect any data. We will write down your practice scores, but only to keep track of your improvement.

Today we will do the first three tests. When you come back we will do the last two tests, measure your hand, and also ask you questions about the fit and comfort of the gloves. In addition, please tell us if you have any comments about the gloves while you are doing the tests.

Minnesota Rate of Manipulation Turning Test

Instructions:
(The subject stands in front of the board.)

This is a timed test to see how fast you can turn the blocks over. You will turn all of the blocks over, and your score will be the amount of time it takes to finish.

Start with your left hand on the upper right-hand block. When I say "go", pick it up with your left hand, turn it over and, with your right hand, put it back bottom side up, into the same hole, like this (demonstrate). Work to the left across the top row, picking each block up with your left hand and putting it down with your right hand. When you reach the end of the first row, you will change directions and work left to right across the second row, picking up the blocks with your right hand, turning them over, and replacing them with your left hand. Each time you finish a row, change directions, and always pick up the blocks with your leading hand and put them down with your following hand. Before you finish, make sure that every block is all the way down. If you drop a block on the table or floor, the trial will be started over.

Roeder Manipulative Aptitude Test--Rods and Caps

Instructions:
(Position the test so that the pieces are at the bottom of the board, closer to the subject.)

The object of this test is to assemble as many rods and caps as you can. You will have one minute for each practice trial, and two minutes for each trial after data collection begins.

Begin with a rod in your dominant hand, with your hand resting on the table next to the board. When I say "go", screw the rod into the top socket on the board, opposite your dominant hand (demonstrate). Then pick up a cap and screw it onto the top of the rod. Alternate rods and caps in this way, always working across each row in the same direction. Make sure the caps are screwed all the way on the rods, and not just balanced on top. You will be scored by the total number of pieces you put together (rods plus caps) but if any caps can be knocked off they will not count. There are enough extra pieces so that if you drop one you should ignore it and replace it with another from the well.

Purdue Assembly Test

Instructions:
(Place the board in front of the subject with the wells at the top.)

This is a two-handed test. You will assemble the pins, washers, and collars like this (demonstrate), using both hands alternately to place a pin in the board, a washer on the pin, a collar on top of the pin and washer, and finally a second washer on the pin and collar. The sequence of parts is always the same and you will always use your right hand for the pins and collars and your left hand for the washers. While you are placing a piece with one hand, reach for the next piece with the other hand to save time.

Begin with a pin in your right hand, and both hands resting on the table by the sides of the board. When I say "go", place the first pin in the upper hole of the right-hand column. Practice trials and trials for data collection all last one minute apiece. Your score will be the total number of pieces used in the assemblies. There are enough pieces so that you do not need to use any pieces that you might drop; instead, go back to the wells to replace them.

[Note: if the subject knocks off the top washer from a completed assembly during a trial, the washer still counts. The subject should not replace the washer.]

O'Connor Finger Dexterity Test

Instructions:
(Place test in front of the subject with the rows of holes toward him or her and the well at the top of the board.)

This is a one-handed test. Use your dominant hand. Start with three pins in your hand with your hand resting on the table by the board. When I say "go", put these pins in the top corner hole opposite your hand. Continue placing the pins three at a time in the holes, always working in the same direction across the rows. If you drop pins, you should pay no attention to them, but pick up new pins from the well to replace them so that each hole contains three pins. Try to pick up three and only three pins at a time.

You will have one minute for each practice trial and two minutes for each trial after data collection begins. Your score will be the number of holes containing three pins.

Pennsylvania Bi-Manual Worksample-Assembly

Instructions:
(Place the board in front of the subject, long edge parallel to the edge of the table, with the bolts under the dominant hand.)

This test measures how quickly you can thread bolts into nuts and place them into holes, like this (demonstrate). Your score will be the number of assemblies placed in the board. You will have one minute to work during practices, and two minutes for each trial after we begin collecting data.

You will use your dominant hand to pick up bolts and your other hand for the nuts. You begin with one piece in each hand, and both hands resting on the table at the ends of the board. When I say "go", thread the bolt into the nut and use your non-dominant hand to put the assembly into the corner hole farthest from your dominant hand. Work across the rows, toward your dominant hand. If a nut falls into a hole, skip that hole and go on to the next. It is not necessary to thread the bolt more than a half-turn into the nut -- just far enough to hold them together. If you drop a piece, pay no attention to it but pick another from the well.

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